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Report #7

RELATIVE EFFICIENCIES OF DUST SAMPLING DEVICES AS APPLIED TO THE COLLECTION OF T-DUSTS

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ABSTRACT

As a result of tests of 8 types of sampling apparatus as well as 9 filter papers in collecting T-dusts (median particle-size: approximately 0.6μ, concentration: 20 mg per cubic meter), the Filter Paper Dust Sampler with a suitable filter paper proved most efficient. This conclusion was based upon

a) the greater efficiency of the Filter Paper Dust Sampler as compared with that of the glass electrostatic precipitator, the Midget or Greenburg-Smith Impinger;

b) the ease of sampling;

c) the accuracy and ease of weighing;

d) the ease of analysis;

e) the uniformity of results;

f) the inexpensiveness of construction and operation.

H-45 paper was superior to all filter papers tested. The usefulness of this paper was limited, however, by the difficulty encountered in analysis, so that in practice Whatman Paper #41 employed in the Brass Filter Paper Dust Sampler was the device of choice when chemical as well as gravimetric analyses of T-dust are desired.

Signed H. P. Dygert

H. P. Dygert

22 November 1944

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Pharmacology Report #7

RELATIVE EFFICIENCIES OF DUST SAMPLING DEVICES AS APPLIED TO THE COLLECTION OF T-DUSTS

Although the efficiency of a number of dust sampling devices is generally known, their effectiveness in collecting T-dusts of known concentration and particle-size has not been investigated. The purpose of this study was to determine the relative efficiency of some commercially used dust-samplers and that of certain less well-known devices, as well as some of the new filtering media in collecting T-dusts. The sampling apparatus and media were tested on three T-dusts: "Hi-Grade" T-ore (Section I), TF_4 (Section IIA) and TO_2F_2 (Section IIB).

Materials and Methods

The 8 types of sampling apparatus and 9 filter papers tested are listed below:

Sampling Apparatus

1. Brass Filter Paper Dust Sampler
2. Filter Paper Mask Sampler
3. Wooden Filter Paper Dust Sampler
4. Glass Electrostatic Precipitator "Standard"
5. Glass Electrostatic Precipitator, Long Model
6. Neilson Filter Paper Dust Sampler
7. Greenburg Impinger
8. Midget Impinger

Filter Papers

1. Whatman #41
2. Whatman #42
3. Whatman #50
4. Balston #50
5. OR-1661-A
6. H-42
7. H-45
8. H-49
9. H-51

1. Brass Filter Paper Dust Sampler (FPDS) was modeled after that used by Fairhall[1] and consisted of 2 machine-faced metal surfaces between which a weighed circular piece of filter paper was held by screwing the parts together. The whole was inserted into the wall of the dust chamber and attached to a suction airline with controlled flow. Figure 1 shows the scale drawing of the FPDS.

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1) Public Health Bulletin #253.

[redacted]

2. Filter Paper Mask Sampler (FPMS) was similar in design and principle to that of the FPDS and was used in attachment with a right-angled Pyrex glass tube of 35 mm outside diameter. At one end of the respirator mask to be tested, at a distance of 25 cm from the respirator, the body of the FPMS is placed. The surfaces of this device were fastened in position with four bolts to retain the filter paper (Figure 2)1

3. Wooden Filter Paper Dust Sampler was similar to the FPMS, save for its composition. The scale drawing of this device is shown in Figure 3.

4. The "Standard" Electrostatic Precipitator (Ep) was a glass model made according to the description in the U.S. Bureau of Mines Information Circular #7086. One of four of these precipitators was selected for the tests recorded in Section I. Comparison of the four precipitators is given in Section IIA.

5. Elongated Model of the Electrostatic Precipitator was identical with the "Standard" with the exception that the inner collecting tube, the wire electrode, and the grid, were extended to 11 inches in length (instead of the conventional 8" length).

6. The Neilson Filter Paper Dust Sampler[1] consisted of a 2-inch Buchner funnel, in the filtering surface of which was placed a Balston #50 filter paper. The device was inserted in the wall of the dust chamber and the stem attached to a controlled suction line.

7 & 8. Greenburg-Smith Impinger and Midget Impinger (I) are standard devices commercially available at the Mine Safety Appliances Company, Pittsburgh, Pennsylvania.

Filter Paper

The H-papers were made of asbestos especially designed to retain dusts of small particle-size and to offer low resistance to high rates of air-flow. The OR-1661-A was a cellulosic paper not yet commercially available. The other papers were obtained commercially.

The filter paper and electrostatic precipitator samples were analyzed gravimetrically and chemically, the impinger samples by the chemical method only. T was analyzed by a modification of the ferrocyanide method of Benard and Tessier[2]

1) Courtesy of Respiratory Laboratory, University of Chicago, Chicago, Illinois.

2) Report #2, Rochester Area, Pharmacology Division, Inhalation Section.

Procedure

The sampling devices and filtering media were tested through apertures in the sides of a 4-foot cubic chamber (see Figure 4) the atmosphere of which contained chemically analyzed concentrations of T-dusts of 2 and 20 mg per cubic meter and median particle-size 0.56μ. The dust was fed into the chamber through the roof by an adjustable speed mechanical feeder onto a moving electric fan. The rate of airsampling unless otherwise indicated was 32 liters per minute.

As a basis for the determination of comparative efficiencies of samplers and papers, Whatman #41 was selected as the reference standard. Previous work had indicated the high efficiency of this paper. The effect of the location of the sampling device was then established using this paper (Table I). The Ep and FPMS were not corrected because, variations in pepeated tests far exceeded those due to positional effects and because the FPMS was uniformly used in position X_2. Position 01 (Figure 4) was selected as the reference site. Whatman Filter Paper #41 used in the wooden FPDS was always used at this site. The 7 types of filter papers and 8 types of ap aratus were then tested for relative efficiencies in the retention of T-dusts by comparison with Whatman #41 paper used in the FPDS (Table II). Tests were carried out in atmospheres containing approximately 20 mg per cubic meter in the majority of the sampling periods. Concentrations of 2 mg per cubic meter were also used for comparison.

Results

The results are divided into three parts, Sections I, IIA, and IIB, because the differences in the properties of the T-dusts used in the tests and the different groups of sampling apparatus required separate treatment.

Section I

COMPARATIVE EFFICIENCY OF 6 DUST SAMPLERS AND 8 FILTER PAPERS IN "HI-GRADE" T-ORE DUSTS

Of 6 dust-collecting devices and 8 types of filters tested in 29 sampling periods in which various combinations of these media were used, H-45 paper used in the brass FPDS proved to be the most efficient method of dust-collection.

The FPMS closely approximated the efficiency of the brass FPDS when Whatman #41 paper was used in each. In separate tests, comparative efficiency values for the FPMS were 104 and 99.5% as against 115 and 101%, respectively, for the FPDS (Table II, Sections D and E).

The elongated model of Ep exhibited a varying efficiency depending upon the dust concentrations. At dust concentrations of 2 mg per cubic meter, the elongated precipitator had an efficiency of 100% which was somewhat higher than the efficiency of the "Standard". No difference in efficiency of dust collection was noted in the two models, however, at 20 mg per cubic meter of T-dust (Table II, Sections F and D).

As shown in Table II, Sections I, J, K, L, the H-papers were superior to the other papers tested. Their usefulness, however, was limited owing to the difficulty of recovering the dust from the paper for analysis. Analytical procedure with these filters is more difficult than with cellulosic papers e.g. Whatman and OR-1661-A. OR-1661-A was inferior to Whatman #41 (Table II, Section H).

The resistance to airflow of the papers, with the exception of Whatman #42 and #50, was sufficiently low so that air-sampling rates of 32 liters per minute could be used.

Complete data are given in Table II. For convenience the relative efficiencies of the dust-sampling devices and filter papers tested for collection of T-ore are summarized below:

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Table II

Dust Sampling Devices	Relative Per-Cent Efficiency
Brass Filter Paper Dust Sampler	115[1]
Filter Paper Mask Sampler	104[1]
Wooden Filter Paper Dust Sampler	100[1]
Nielson Filter Paper Dust Sampler	90[1]
Elongated Electrostatic Precipitator	92[2]
"Standard" Electrostatic Precipitator	78
Filter Paper	
H-45	123
H-42	114
H-51	111
H-49	108
Whatman #41	100
Whatman #42	98
OR-1661-A	80
Whatman #50	55

Section IIA

COMPARATIVE EFFICIENCY OF MIDGET IMPINGER, ELECTROSTATIC PRECIPITATOR, AND FILTER PAPER DUST SAMPLER IN SAMPLING TF_4 DUST

1. The results of sampling an atmosphere containing TF_4 dust by means of the Midget Impinger using water as the collecting medium and by means of the Filter Paper Dust Sampler are shown in Table III. In all tests, the amounts of TF_4 collected by the FPDS were greater than those collected by the Midget Impinger. Moreover wider variations were observed in the amounts collected in repeated trials by the Midget Impinger than in those collected by the FPDS.

2. Results of comparative tests of efficiency (made in triplicate) of the electrostatic precipitator and FPDS in collecting TF_4 dust are shown in Table IV. Four glass electrostatic precipitators which had been made as nearly as possible identical but with voltage adjusted to suit each instrument, were compared to determine the variation of each instrument.

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1) Whatman #41 filter paper was used as the collecting medium.

2) The efficiency of this device was dependent on the dust concentration sampled. Its relative efficiency was 100 at 2 mg per cubic meter, 83 at 20 mg per cubic meter. The figure above represents the combined average of these efficiencies.

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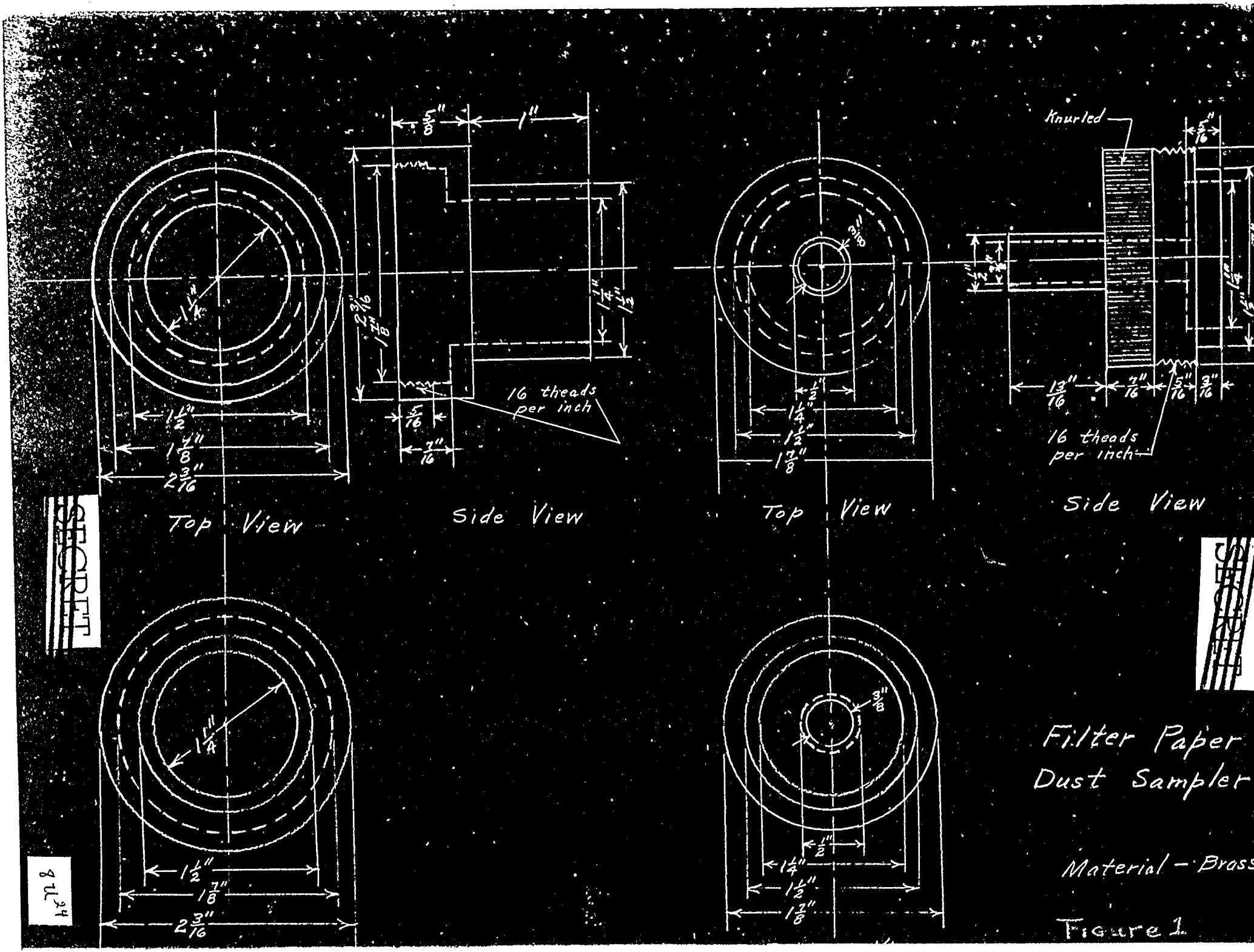
5/8"
1"
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1 7/8"
1 1/4"
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16 theads per inch
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1 1/4"
1 1/8"
2 3/16"
Top View
Side View
3/8"
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1 1/2"
1 7/8"
Top View
Knurled
5/16"
1 1/4"
1 1/2"
13/16"
7/16"
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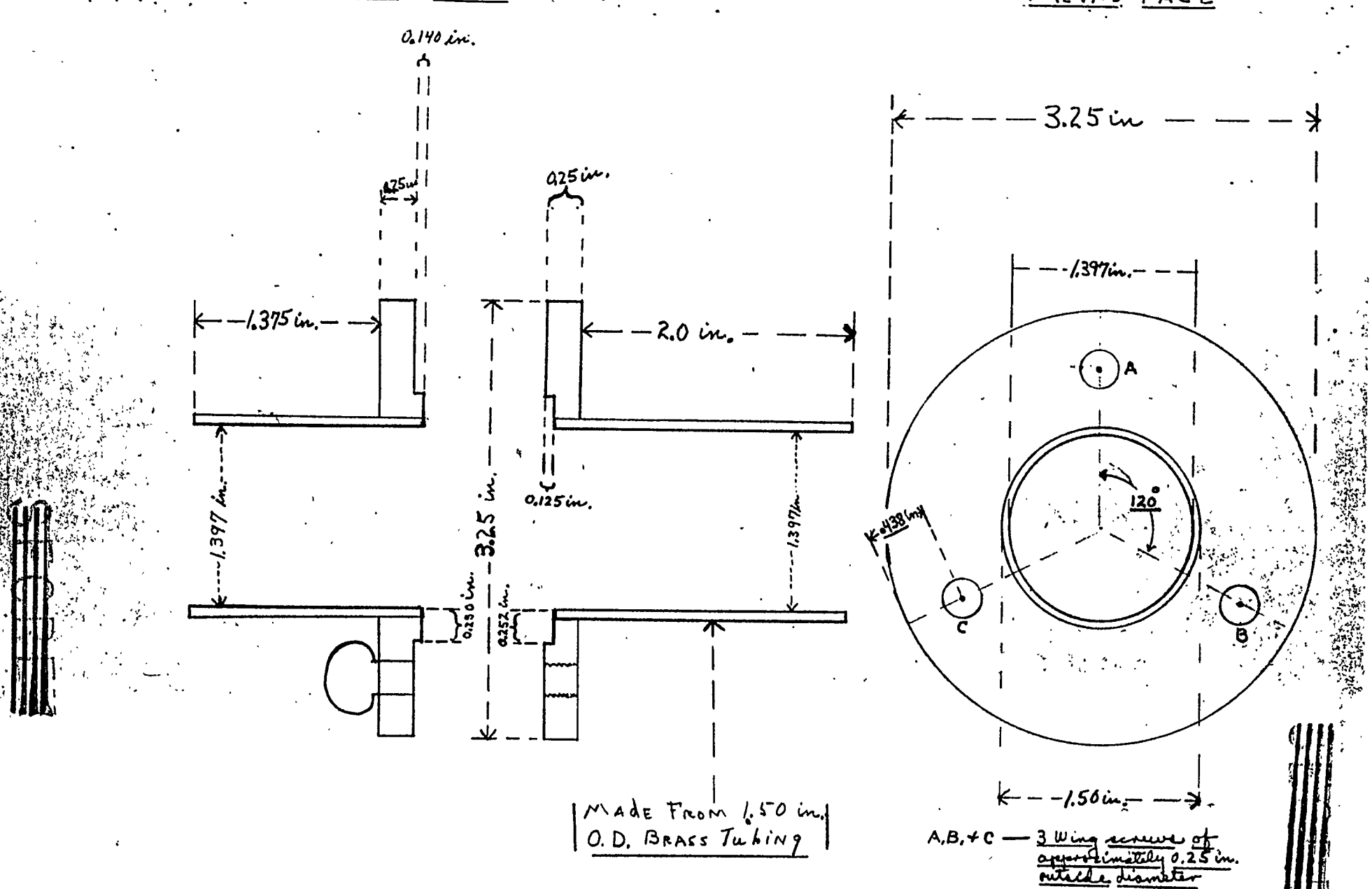
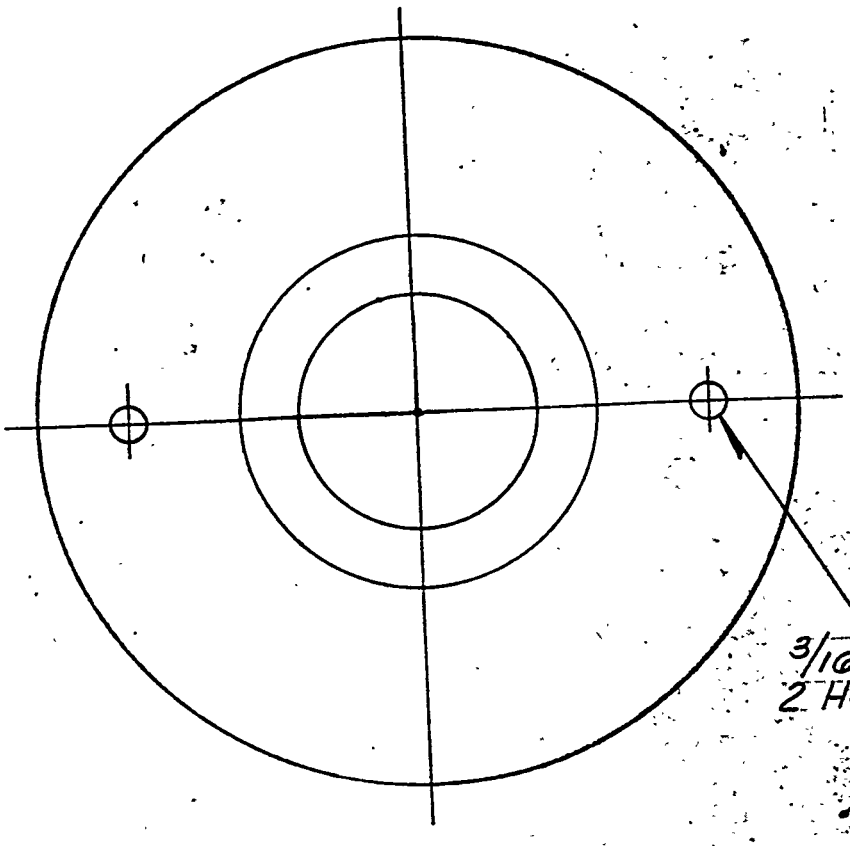
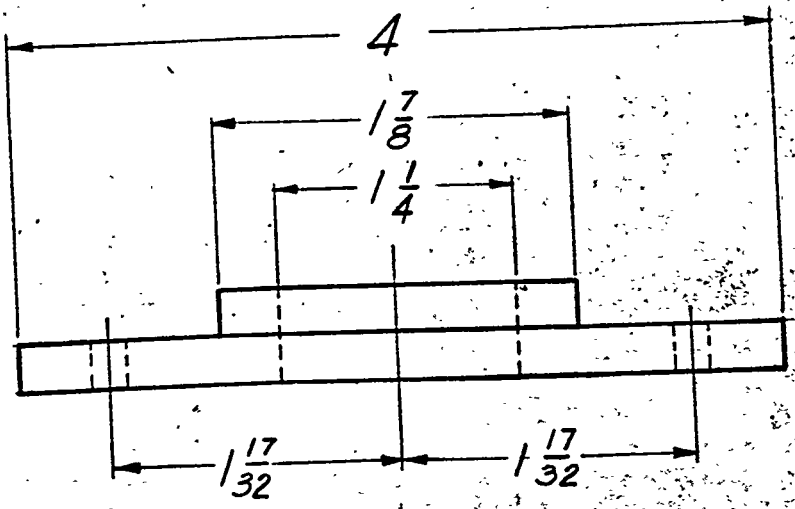
3/16"
16 theads per inch
Side View
SECRET
1 1/4"
1 1/2"
1 7/8"
2 3/16"
3/8"
1/2"
1 1/4"
1 1/2"
1 7/8"
Filter Paper Dust Sampler
Material - Brass
Figure 1.



BRASS FILTER PAPER MASK SAMPLER

Figure 2



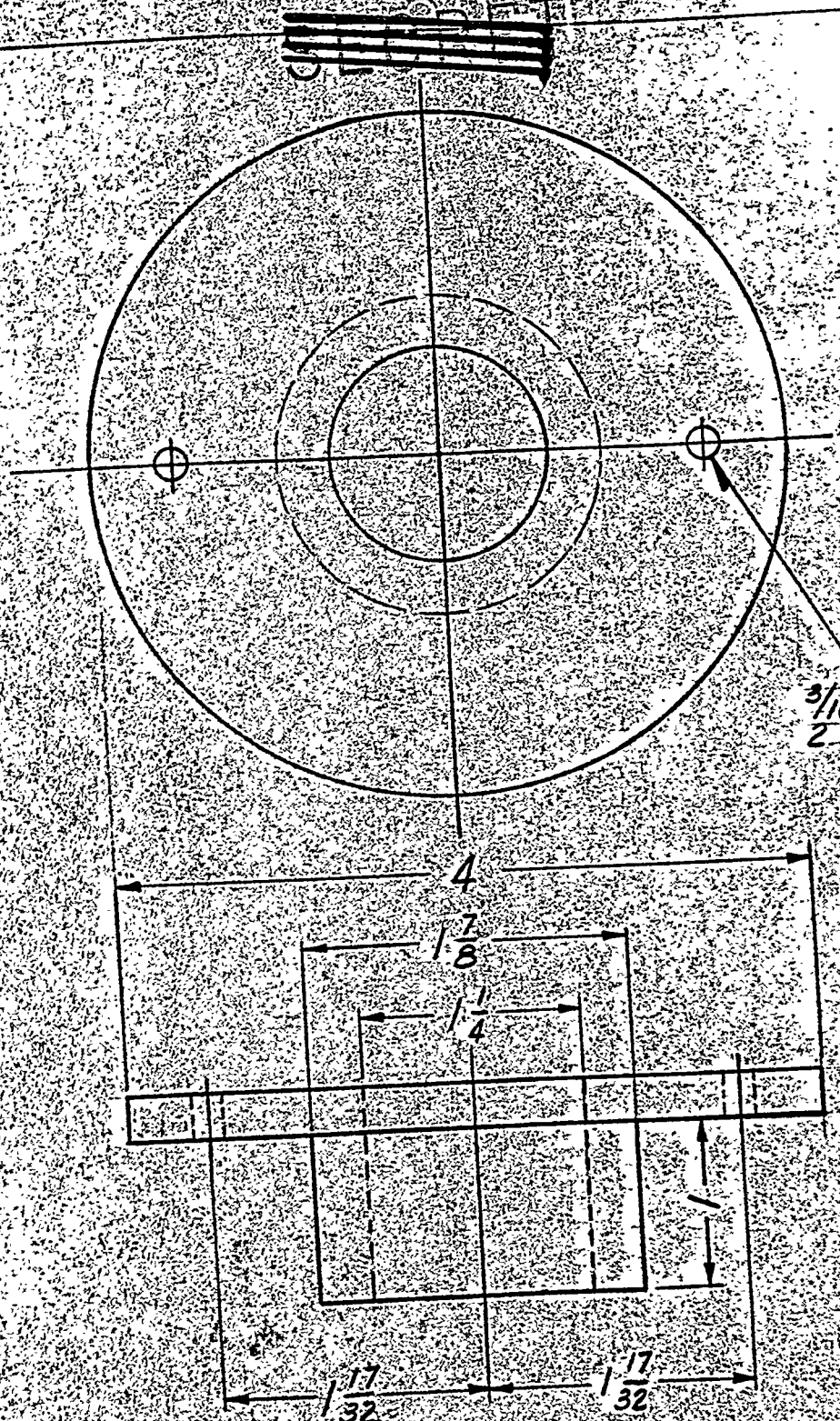


1/4 3-PLY

FILTER PAPER
DUST SAMPLER
SCALE - 1/1
ENG.-H.P.D. DR.-M.C. CH.- A.P.D.
2-17-44

D-20A

Figure 3a



1/4 3 PLY

FILTER PAPER
DUST SAMPLER
SCALE 1/1

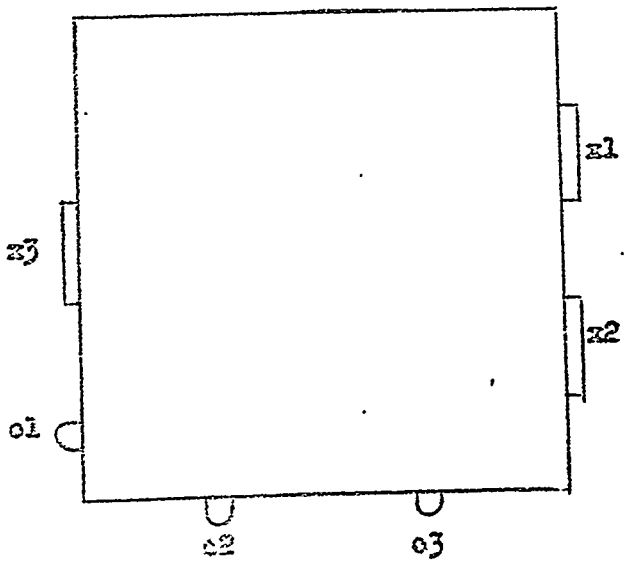
ENG- H.R.D. DR- M.C. CH- H.P.D.
2-17-44

D-20B

Figure 3b

[redacted]

Figure 4



x = positions at which respirator filter efficiencies are tested utilizing electrostatic precipitators and the filter paper mack sampler. (Referred to in Table III.)

o = positions at which filter paper dust samplers are used in taking samples for determining chamber air concentrations. (Referred to in Table III.)

[redacted]

[redacted]

TABLE I

WEIGHTING OF SAMPLING POSITION IN CHAMBER RELATIVE TO AMOUNT OF DUST RETENTION

Whatman Paper #41

Sampling Period	Position o1	Position o2	Position o3
	Milligrams of Dust Retained as T per Cubic Meter		
I	14.8	16.7	15.8
II	6.2	7.4	7.5
III	8.6	10.4	9.8
	Per Cent Retention		
I	100	113	107
II	100	119	121
III	100	121	114
Average	100	117	114
Factor Weighted for Position	1.00	0.855	0.877

[redacted]

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[redacted]

TABLE II

RELATIVE EFFICIENCY OF DUST SAMPLING APPARATUS AND OF FILTER PAPER COMPARED TO WHATMAN #41 PAPER

A Sampling Period	Reference Position c1 Whatman 41	Test Position c2 Whatman 42	Test Position c3 F.P.D.S.
	Milligrams of Dust Retained as T per Cubic Meter		
IV	13.1	9.5	9.5
V	9.8	9.3	9.3
VI	3.3	5.4	4.8
VII	29.9	29.3	24.4
	Average Per cent Retention, Weighted for Position (Table I)		
	100	101	94
	Combined Average		97.5

B Sampling Period	Reference Position c1 Whatman 41	Test Position c2 Whatman 50
	Milligrams of Dust Retained as T per Cubic Meter	
VIII	4.9	3.3
IX	5.0	3.3
X	6.0	3.8
	Average Per Cent Retention, Weighted for Position	
	100	55
	Average	55

[redacted]

142[24]

[redacted]

TABLE II (Cont'd)

C

Sampling Period	Reference Position o1 Whatman 41	Test Position x2 Whatman 41, F.P.M.S.
	Milligrams of Dust Retained as T per Cubic Meter	
VIII	4.9	5.6
IX	5.0	5.9
X	6.0	6.8
	Average Per Cent Retention	
	100	115
	Average	115

D

Sampling Period	Reference Position o1 Whatman 41	Test Position o2 Nielson F.P.D.S.	Test Position o3 Whatman 41 Brass F.P.D.S.	Test Position x2 F.P.M.S.
	Milligrams of Dust Retained as T per Cubic Meter			
XXVI	17.5	18.1	20.2	17.4
	Average Per Cent Retention, Weighted for Position			
	100	88	101	99.5[1)]

1) Indicates values not weighted.

[redacted]

TABLE II (Cont'd)

E

Sampling Period	Reference Position o1 Whatman 41	Test Position o2 Nielson F.P.D.S.	Test Position o3 Whatman 41 Brass F.P.D.S.	Test Position x2 F.P.M.S.
	Milligrams of Dust Retained as T per Cubic Meter (Dust concentration in chamber of 2 mg per cubic meter)			
XXIII	1.8	1.9	2.2	1.9
XXIV	1.5	1.6	2.3	1.6
XXV	1.8	2.0	2.2	1.8
	Average Per Cent Retention, Weighted for Position			
	100	90	115	104[1]

F

Sampling Period	Reference Position o1 Whatman 41	Test Position x1 Ep, Standard	Test Position x3 Ep, Long
	Milligrams of Dust Retained as T per Cubic Meter		
I	14.8	11.4	6.5
II	6.2	5.4	4.4
III	8.6	8.0	6.2
IV	13.1	11.2	10.4
V	9.8	7.6	8.8
VI	3.3	3.9	2.7
XXVIII	14.8	11.0	13.8
XXIX	19.3	17.0	16.5
VIII	4.9	3.6	3.7
IX	5.0	4.4	5.2
X	6.0	5.5	6.5
XXVI	17.5	13.1	15.1
	Average Per Cent Retention		
	100	83	83

[1] Indicates values not weighted.

[redacted]

TABLE II (Cont'd)

G

Sampling Period	Reference Position o1 Whatman 41	Test Position x1 Ep, Standard	x3 Ep, Long	x2 F.P.M.S.
	Milligrams of Dust Retained as T per Cubic Meter (Dust concentration in chamber air 2 mg per cubic meter)			
XXIII	1.8	1.6	1.8	1.9
XXIV	1.5	1.0	1.6	1.6
XXV	1.8	1.4	1.7	1.8
	Average Per Cent Retention			
	100	78	100	104

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H

Sampling Period	Reference Position o1 Whatman 41	Test Position o2 OR-1661-A	o3 OR-1661-A
	Milligrams of Dust Retained as T per Cubic Meter		
XI	11.7	7.8	-
XII	6.1	5.7	6.2
XIII	6.9	6.6	6.7
	Average Per Cent Retention as T per Cubic Meter		
	100	73	87
	Combined Average		80

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I

Sampling Period	Reference Position o1 Whatman 41	Test Position o2 H-42	o3 H-42
	Milligrams of Dust Retained as T per Cubic Meter		
XIV	8.0	10.2	11.4
XV	10.8	14.4	13.2
XVI	15.2	19.6	19.6
	Av. Per Cent Retention as T per Cubic Meter weighted for position		
	100	111	117
	Combined Average		114

[redacted]

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[redacted]

TABLE II (Cont'd)

J

Sampling Period	Reference Position o1 Whatman 41	Test Position o2 H-45	Test Position o3 H-45
	Milligrams of Dust Retained as T per Cubic Meter		
XVII	5.2	6.9	7.8
XVIII	4.5	6.0	6.3
	Average Per Cent Retention as T per Cubic Meter Weighted for Position		
	100	116	129
	Combined Average		123

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K

Sampling Period	Reference Position o1 Whatman 41	Test Position o2 H-49	Test Position o3 H-49
	Milligrams of Dust Retained as T per Cubic Meter		
XX	17.8	22.2	22.2
	Per Cent Retention as T per Cubic Meter Weighted for Position		
	100	107	110
	Combined Average		108

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L

Sampling Period	Reference Position o1 Whatman 41	Test Position o2 H-51	Test Position o3 H-51
	Milligrams of Dust Retained as T per Cubic Meter		
XXI	13.5	16.6	18.1
XXII	22.5	29.0	28.0
	Average Per Cent Retention as T per Cubic Meter Weighted for Position		
	100	108	114
	Combined Average		111

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TABLE II (Cont'd)

M Sampling Period	Reference Position o1 Whatman 41	Test Position o2 H-17	Test Position o3 H-18
	Milligrams of Dust Retained as TO_2 per Cubic Meter		
1	5.67	4.93	5.60
2	5.64	5.14	4.42
3	3.27	-	2.79
	Average Per Cent Retention Weighted for Position		
	100	76	77

[redacted]

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[redacted]

TABLE III

COMPARISON OF FILTER PAPER DUST SAMPLER (F.P.D.S.) AND MIDGET IMPINGER IN SAMPLING OF CHAMBER AIR CONTAINING TF_4

Median Particle-Size M_g = 0.8μ σ_g 2.50[1)]

F.P.D.S.		MIDGET IMPINGER	
Volume of Air Sampled	Amount TF_4 Collected	Volume of Air Sampled	Amount TF_4 Collected
cu m	mg/cu m	cu m	mg/cu m
0.200	53.0	0.020	37.1
0.200	78.0	0.020	70.8
0.200	56.6	0.020	29.6
0.140	46.6	0.014	43.5
0.140	53.0	0.014	31.5

1) M_g represents the median of the particle-size distribution, which is approximately the geometric mean. For dusts, the M_g value is expressed in micra, μ. It is obtained by reading off the 50 per cent size from a logarithmic-probability graph constructed from the size-frequency of the particles, e.g. $M_g = 0.6\mu$ states that the median diameter of the particles sampled is 0.6μ. 50 per cent of the samples are equal to or less than this value.

σ_g is a measure of the dispersion of particle diameters from the geometric mean. It is computed from the logarithmic-probability graph according to $\frac{\text{84.13 per cent size}}{\text{50.00 per cent size}} = \sigma_g$. The larger the value the greater the spread of particle-size. For a more extensive discussion, see Hatch & Choate, J. Franklin Inst., 207, 369, 1929.

[redacted]

TABLE IV

COMPARISONS OF EFFICIENCIES OF FILTER PAPER DUST SAMPLER (F.P.D.S.) AND 4 GLASS ELECTROSTATIC PRECIPITATORS (Ep) IN CHAMBER AIR CONTAINING TF_4

Median Particle-Size M_g = 0.8 μ σ_g = 2.5

Type of Sampling Apparatus	Volume of Air Sampled	Total Sample Collected (chem. anal.)	Weight of Sample (chem. anal.)	Efficiencies as Compared with F.P.D.S.
	cu m	mg	mg/cu m	per cent
F.P.D.S.	0.44	7.48	17.0	100.0
Ep #1	0.32	4.29	13.4	78.0
Ep #2	0.32	3.23	10.3	60.5
Ep #4	0.32	4.57	14.3	84.0
F.P.D.S.	0.41	3.00	7.3	100.0
Ep #1	0.32	1.33	4.2	57.0
Ep #2	0.32	1.52	4.8	65.3
Ep #4	0.32	1.63	5.1	69.6
F.P.D.S.	0.49	3.54	7.2	100.0
Ep #1	0.32	1.94	6.1	84.3
Ep #2	0.32	1.67	5.2	72.5
Ep #4	0.32	1.49	4.7	64.8
F.P.D.S.	2.00	12.10	6.1	100.0
Ep #3	1.28	5.11	4.0	66.7
F.P.D.S.	1.62	4.60	2.9	100.0
Ep #3	0.96	1.98	2.1	71.0
F.P.D.S.	1.16	3.23	2.8	100.0
Ep #3	0.83	1.70	2.1	75.0

	Average Efficiency (3 determinations)	
	Order	Per Cent
F.P.D.S.	1	100.0
Ep #1	2	73.1
Ep #3	3	72.8
Ep #4	4	70.9
Ep #2	5	66.1

[redacted]

TABLE V

COMPARISON OF GLASS ELECTROSTATIC PRECIPITATOR (Ep) AND THE GREENBURG-SMITH IMPINGER (I) IN SAMPLING CHAMBER AIR CONTAINING TO_2F_2

Median Particle-Size, Mg $0.6\mu\sigma g = 2.24$

Type of Dust-Sampling Apparatus	Air Volume	Weight of Sample (Chem. Anal.)	Weight of Sample
	cu m	mg	mg/cu m
Ep #1	0.32	1.98	6.20
Ep #3	0.32	2.08	6.50
I	0.29	2.09	7.20
Ep #1	0.32	1.60	4.44
Ep #3	0.32	1.00	3.13
I	0.29	2.09	7.20
Ep #1	0.32	3.00	9.38
Ep #3	0.32	2.70	8.55
I	0.29	3.52	12.10

[redacted]

Each glass precipitator was less efficient than the FPDS using Whatman #41 paper as the filtering medium. The average efficiency of the glass electrostatic precipitators operating at approximately 20,000 volts was 70 ± 4% compared to the efficiency of the FPDS as 100.

Section IIB

COMPARATIVE EFFICIENCIES OF THE GREENBURG-SMITH IMPINGER AND THE ELECTROSTATIC PRECIPITATOR IN COLLECTING TO_2F_2 DUST

The results of the comparative testing of 2 glass electrostatic precipitators and a large Greenburg-Smith Impinger, using water as the collecting medium, showed that the efficiency of the impinger was equal to or greater than that of the Ep in collecting TO_2F_2, an extremely soluble T-dust (Table V).

Conclusions

The Filter Paper Dust Sampler, used with a suitable filter paper, is the device of choice for sampling T-dusts in atmospheres. This conclusion is based on: (1) the greater efficiency of the FPDS compared to the glass electrostatic precipitator (Table IV), or the Midget or Greenburg-Smith Impinger (Table III, V); (2) the ease of sampling; (3) accuracy and ease in weighing; (4) ease and speed of analysis; (5) uniformity of results; (6) inexpensiveness of construction and operation.

H-45 paper used with the FPDS showed the greatest efficiency of all papers tested. The usefulness of this paper was limited by the difficulty encountered in analysis of the absorbed dust so that, practically, Whatman paper #41, employing the brass FPDS, proved superior when chemical as well as gravimetric analyses of T-dust are desired.

Signed H. P. Dygert
H. P. Dygert

22 November 1944